Conceptual framework(s) for cost analysis

The Role of Economics in Habitat Restoration

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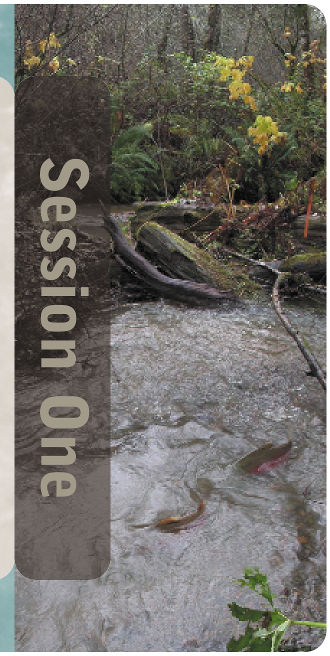


ABSTRACT

Whenever habitat restoration planners choose to fund certain projects within a limited budget, economic information should help them understand and assess the trade-offs they are facing. In particular, by focusing on the costs and expected achievements of projects, economics promotes selection of projects that achieve as much restoration as possible for any given effect on the human economy. At the simplest level, an economic **cost analysis** demonstrates what is given up in order to accomplish a particular restoration objective. A more complex approach, the **cost-effectiveness analysis**, pairs the costs for alternative projects with a measure of project effectiveness or accomplishment. A more challenging approach – the **benefit-cost analysis** – estimates the value of project accomplishments in tandem with costs of projects. Finally, **economic impact analysis** assesses likely changes in regional incomes, employment or sales associated with a restoration project. Ultimately, economic tools focus on broad trade-offs inherent in funding salmon restoration – such as the balance between assuring sustained timber supply or electrical power and protecting and enhancing fish and wildlife. In salmon recovery planning in the Columbia river basin, all four economic analysis tools have been used in a variety of contexts. Under the Endangered Species Act economic considerations have a limited role in the key decision to list species. However, economic analysis should help decision-makers understand and evaluate the economic and other consequences of choosing a particular mix of restoration projects.

INTRODUCTION

Some standard economic evaluation tools can be used to assist in decision making about salmon habitat restoration projects. I will briefly describe four of these: cost analysis, cost-effectiveness analysis, benefit-cost analysis, and economic impact analysis. Any or all of these may be appropriate in specific circumstances. A problem in applying these to salmon habitat restoration is the difficulty of linking the costs of specific restoration activities to the broad objectives of salmon restoration, which typically include increased numbers and genetic diversity of naturally spawning fish. To describe the costs of achieving salmon recovery objectives requires that information about habitat restoration activities be supplemented by estimates of effects on salmon stocks. I provide a general framework for thinking about these connections between project activities/costs and the restoration objectives. Regarding the role of economic assessment/evaluation under the Endangered Species Act (ESA), I conclude that, while the role of economics is restricted, it can be a useful tool in screening and selecting recovery plan elements. Finally, I address a number of problems that arise in the practice of economic assessment in both salmon restoration and general natural resources planning.

FOUR ANALYTICAL TOOLS

Cost analysis attempts to understand and measure what is sacrificed to implement a specific project or to accomplish a particular objective. While sacrifices may be of various types, the goal of cost analysis is to sum up the sacrifices in terms of a common unit of measurement. Economists use the standard metric of currency units, mainly because those are the units in which people commonly express many small decisions to sacrifice one thing for another — for example, in making spending and taxing decisions. Economic costs include the obvious direct costs (e.g., personnel costs, materials, supplies, overhead, energy costs) and also opportunity costs — the value of other things given up in accomplishing the habitat restoration objective. When the project is fully paid for by the agency doing the rehabilitation, all the costs are direct costs and would show up as monetary costs in the agency budget. For example, the costs of replacing a culvert under a mountain road may be completely accounted for by the sum of materials, labor, and road machinery rental costs incurred by the agency.

On the other hand, if the agency strives to improve fish access through culverts by imposing and enforcing standards for culverts, then the costs would not show up as items in the agency's budget. Instead, they could appear as direct costs to road builders or landowners. Further, if roads are removed or decommissioned, there may be other opportunity costs — the value sacrificed in using those roads for recreation, access to timber, and fire control. In streamside habitat rehabilitation projects, for example, we may want to fence cattle away from a stream to protect vegetation within 100 feet or 300 feet of the water. By reducing the area available for grazing we may cause fewer cattle to be raised per acre of pasture. The reduced net profits in cattle production is an opportunity cost of habitat protection — we give up that value in order to use land resources for other purposes.

In Oregon and Washington, public water trusts are buying or leasing water rights from farmers in order to shift more water to instream flow. When farmers will give up their rights to divert water for irrigation, the opportunity cost to them is the reduced income from crops they could produce. If they are willing to lease a water right for, say, $100 per acre-foot per year, this suggests that they think the water would enable them to earn $100/year or less from the sale of additional crops. Hence, a negotiated price for water is a first-cut estimate of the opportunity costs of water in agriculture. Using prices in this manner draws the connection between the opportunity cost and actual cash outlays: the opportunity costs of the water being used in irrigation reflects the price the farmer would sell it for. In effect, the water trusts are paying for a series of water acquisitions at prices that reflect the opportunity costs of taking the water out of the agricultural sector and putting it in the river for fish. If, on the other hand, water is withheld from the farmers via legal action, then the farmer's would absorb the opportunity cost of reduced crop production and the agency demanding the action incurs no direct cost (aside from legal fees and costs of enforcement).

Cost effectiveness analysis incorporates the estimation of costs along with some measure of effectiveness for more than one project, allowing a comparison or ranking of projects. For example, there may be a number of ways to improve stream flow in a particular river reach — purchase of water rights, improved water conveyance facilities, increased upstream storage, or re-vegetation of riparian zone. If you have a limited budget, you may want to select one or a combination of these projects which give you the "biggest bang for the buck". The "buck" is the amount of funds available, and the "bang" is the amount of salmon habitat rehabilitation accomplished. A major challenge in using this technique to assess habitat rehabilitation, in my experience, is the quantification of project effectiveness.

You need a comparable measure of effectiveness across projects, and this generally requires a common unit of accomplishment for disparate kinds of projects. Flow improvements may be measured in terms of flow volume (acre-feet) or rate (cubic feet per second). Instream habitat quality may be measured in area of gravel beds or summer water temperature in deep pools, etc. These are not inherently comparable. One approach would be to establish for each of these the expected increase in juvenile fish survival or increase in numbers of returning adult spawners or the contribution to increased fish harvest associated with each habitat restoration project. Any one of these would provide a common measure of effectiveness.

With the ratio of cost to effectiveness identified for each project, one can then rank the projects in terms of cost-effectiveness. If the program budget is fixed, the projects should be chosen to get the most effectiveness possible within the available budget. To do this, simply choose projects from the top of the cost-effectiveness list, moving down the list until the budget is exhausted. If the program budget is undetermined but the overall program objective is quantified in terms of the effectiveness measure (e.g. an increase of 50% in juvenile salmon production for a stream), then projects could be selected to achieve the objective at least cost. The group of projects would be called the least-cost combination.

This simple approach to achieving cost-effectiveness must be modified, of course, if the projects are mutually exclusive or if the accomplishment of one project affects either the costs or the effectiveness of another project. In this more complex situation, one must evaluate the cost and effectiveness of all logical combinations of projects to determine the most cost-effective package of restoration actions.

Benefit-cost analysis is more comprehensive and demanding of information, because it requires quantitative measures of the value of achieving the program objectives (the benefits). Because the benefits and costs are expressed in similar units, one can compare these directly on an absolute scale. So, spending additional amounts on specific habitat restoration projects generates benefits in terms of commercial, recreational, and tribal fish harvests. If the quantified benefits exceed the quantified costs, the decision to spend more can be justified by the economic criteria that the public, collectively, is gaining more than it is losing.

When the objectives are expressed in terms of fish caught (rather than biodiversity preservation or aesthetics of natural habitats), the estimation of benefits can be relatively straightforward using techniques developed over the past three decades by environmental economists (Freeman 1993). Because the value of salmon harvest increases at a decreasing rate (that is, the marginal value declines), there is a point at which the value of increased harvests will fall below the cost of getting the increased harvest. We may not be at that point yet, but a benefit-cost framework would help to determine when we should stop spending on salmon habitat restoration and spend on something else. Even in salmon restoration, we may eventually want an estimate of the benefits of the program.

Finally, **economic impact analysis** generally measures the changes in the regional economy due to a program or policy. Hewings (1985) is a useful introductory text on the models. The economic changes are measured as increase or decrease in aggregate sales, or income, or employment. For example, if federal forest policy reduces the annual cut when shifting forest land from lumber production to wildlife habitat, there is going to be an effect on the local community. Because this effect is not captured entirely by a typical benefit-cost analysis, local communities and politicians may be interested in considering the effect of the policy on income and employment in the region. Disruption of the local economy involves social and other costs not explicitly measured in the usual economic cost assessment. In fact, in the framework process called Sub-Basin Planning in the Columbia Basin, being conducted by the Northwest Power Planning Council (NPPC), economic impact analysis is being done along with the other kinds of analyses.

All four of these analytical methods require that we analyze the project consequences relative to some baseline. When confronted with a claim that a particular program generates a great outcome, an economist is inclined to ask “Compared to what?” For project evaluation information to be relevant to a decision-making process, it all has to be cast in terms of a “with” and “without” action. You compare the outcome with the project to the outcome without the project, and this means you have to make some explicit assumption about the course of events in the absence of the project. This includes measuring the difference in the cost, the value, and the impact that is attributable to the project relative to some assumed conditions.

Example: Costs of the Fish and Wildlife Program in the Columbia Basin

A recent document shows that that costs associated with Bonneville Power Administration’s Fish and Wildlife Program amounted to $3.48 billion over the 1978-1999 period (NPPC 2001). Of that total, $961.7 million were “direct expenditures” and the remainder were estimated opportunity costs. The direct expenditure categories were devoted to harvest management (3%), mainstream passage (23%), artificial propagation (32%), and habitat/watershed preservation (42%). During most of that period the expenditures have been guided by the NPPC. After the listings of Snake River chinook and sockeye salmon stocks, and subsequent National Marine Fisheries Service biological opinions, Bonneville Power Administration (BPA) negotiated a memorandum of agreement among Federal agencies that puts a cap on the costs of the program at $435 million per year.

The actual costs of the program will vary widely among wet and dry water years. This is illustrated by flow augmentation in the Snake River and the spill of water over dam spillways during the peak spring out-migration period for chinook smolts. Both of these actions tend to reduce the amount and value of hydropower produced in the basin, but the effect is more severe in dry years. The reasoning goes like this. Storage reservoirs in the system allow operators to shift water flow from the normal high run-off period in the spring to the relatively lower flow periods later in the year. This permits more hydropower generation during the period of relatively high electricity demand in the Pacific Northwest and California. This shifting of flow from spring to later in the year increases the value of the hydropower generation. When stream flow is augmented in the spring via releases from upstream storage reservoirs, more hydropower can be produced in the spring, but it is worth less then. In wet years, the sacrifice of hydroelectric power value is smaller because there is more than enough water to allow increased stream flow and shifting of water to later in the year. In dry years, spring season flow augmentation can be very costly in terms of hydropower opportunity costs. Unfortunately, the salmon are more in need of flow augmentation in dry years, when the opportunity costs of hydropower are higher. Similarly, the plan to divert some water over spillways in order to help migrating juvenile salmon to avoid the turbines will cause reduced hydropower production. That cost also will be lower per acre foot of water spilled in wet years and higher in dry years.

The negotiated cap on BPA's Fish and Wildlife Program cost is an average across many water years. The direct expenditure on the Fish and Wildlife Program is $127 million per year. That annual budget that is allocated to a series of project proposals submitted to the NPPC, which then decides which project to include in the annual program. The BPA administers the approved budget. Over the past decades, a lot of capital investment has gone into fish ladders at dams, juvenile by-pass systems, salmon hatcheries, and barging systems. The cost of those gets transferred to BPA's budget, and through average-cost pricing to the public and private utilities of the region, and then to retail customers of the region.

REQUIREMENTS FOR CONSISTENT COST ESTIMATES

A salmon habitat restoration program may include several things — replanting vegetation, replacing culverts, placing large woody debris in streams, fencing cattle away from the stream, or conservation easements of stream banks or timbered upland. These recovery activities occur over time and space, and they may be funded through difference agencies and planned by different groups. If we cannot get accountings of how much we spend on these various categories, along with monitoring the effects of these activities on fish populations, we'll never be able to look back and learn about the cost-effectiveness or cost-benefit of salmon restoration. It would be helpful to incorporate some routine practices in the cost collection and reporting of these projects in order to have consistent and accurate cost estimates. Some of these are discussed below.

Opportunity Costs

There is confusion in some quarters concerning the meaning and role of opportunity costs. "After all", the thinking might go, "we did not incur an expenditure, so how can we call it a cost?" But it is important to understand that economic cost is not necessarily an expenditure. Cost is the value of things given up in order to change the habitat condition. When market goods and services are purchased to implement a restoration (timber, gravel, machinery rental, laborers) we often assume that the market price, rental rate, or wage is a decent estimate of the opportunity costs or compensation required to obtain those inputs. The expenditures will be a reasonable estimate of economic cost only if the opportunity costs are adequately represented by the dollars changing hands in transactions. For non-market goods (changes in water flow, riparian vegetation, public land use) there is often no market price or dollar transaction that corresponds to the opportunity costs for those resources. These non-market costs often arise due to policies working in the inter-connected economic-ecological system. Hence, to include those costs in the calculation requires special attention to opportunity costs.

Opportunity cost is the value of the alternative resource uses that we won't have due to a restoration action. These costs can accumulate over time at a restoration site as more and more alternative uses for the resources are prohibited. Many opportunity costs are estimated for specific projects at specific places and times. But in a larger concept, most of these are parts of an overall plan where we cumulatively do a variety of things. It would be helpful to group the economic analyses of the opportunity costs into a total cost for a coherent collection of cumulative projects on particular rivers or region, e.g., the John Day or Deschutes rivers.

For example, in the Deschutes basin, a variety of riparian habitats projects have been completed on the Warm Springs Reservation. And the Oregon Water Trust has completed several purchases of water rights that are used to increase in-stream flows.[1] We could analyze each project and purchase to determine the cost (reduced value agricultural production, for example) to improve conditions slightly for some fish at some time of the year. But, what we really want to know is how these costs accumulate over the whole program and how the costs relate to the potential recovery of the fish. What do the cumulative costs and cumulative fish effects look like? If we look at a larger picture than individual water purchases or projects, we may learn a lot more about both the costs and the effectiveness, including how improved habitat for fish increases the numbers of fish and how we can connect that with the costs of doing so.

The following are some specific examples of opportunity costs:

• **Value of crops** sacrificed when we move water from irrigation to instream flow.

• **Value of recreational opportunities** lost. The Snake River is a case in point. If we take out a dam and create a free running river, we get some rafting and other kinds of recreational opportunities, but we give up recreational opportunities associated with the reservoirs. Both of these recreational opportunities have values that can only be estimated through structured study. The economic values won't be evident from data on recreational expenditures or project budgets.

• **Reduced hydropower** valued at its current or projected market value, when water is released to increase stream flow or when water is diverted over spillways instead of through turbines.

• **Reduced flood control** when dam are removed or levies breached. Damage to property and people due to increased flooding would be an opportunity cost of these kinds of restoration projects.

• **Reduced commodity production** from public lands. When we re-allocate resources and watersheds away from natural resource extraction towards restoration and preservation of natural habitat we produce less value in forest products and mining products.

• **Value of labor/capital/land in alternative uses**. The payments for labor on projects is usually represented by the wages paid. If significant volunteer (or coerced) labor is used on the project, then the opportunity costs of that labor would equal the wages that could have been earned in paying occupations. Similarly, the cost of rented capital equipment is adequately represented by rental payments. Equipment that is donated, borrowed or owned by a government agency also has an opportunity cost equal to the value that equipment could

1- For more information about Oregon Water Trust visit their website at http://www.owt.org/

bring in a rental market. Land, also, has opportunity costs. If riparian land is re-allocated to habitat restoration rather than residential, recreational, or agricultural use, its opportunity cost (value in the rental market) should be estimated.

Interim Use Losses

Another category of cost – interim use loss — is imposed on those who lose the use of some resources during the period of recovery. For example, if access to streamside habitats or fishing is curtailed during a 20-year project to rehabilitate streamside vegetation, the people who valued the use of that stream will suffer an economic loss. If the loss consists of non-market or recreational use value, estimation of that loss could be approached through a technique known as the travel cost model. Or more direct valuation methods, normally going by the title of "contingent valuation," could be employed to estimate the magnitude of the lost use value. When market-related losses occur, the lost use value could be approximated as the reduced profit or land rent or incomes associated with the lost use. When such recreational or commercial values are lost year-after-year for an extended period, then the total cost would be computed as the present value of the sequence of annual losses. (Again, see Freeman, 1993, for an extended discussion of the non-market valuation methods.)

Consistency Across Estimates

To compare the costs or benefits of alternative projects, we need to achieve some consistency across the estimates among projects. For example, a School of Marine Affairs student, Emily Anderson, examined a series of Federal Energy Regulatory Commission (FERC) hydropower dam re-licensing cases involving projects that affect fish runs for her thesis. She wanted to determine whether dam removal is the preferred decision when costs of satisfying fish passage requirements, among other things, exceed the value of the dam to the owner. Each FERC re-licensing case requires compilation of an Environmental Impact Statement (EIS). An EIS examines the social and economic effects of the alternative measures being considered. The economic costs and benefits of a re-license proposals are spread out over many years, typically 50 years. To compare the alternatives considered for each dam, and to make comparison across re-licensing cases, we want to express all future years' estimated economic costs and benefits in inflation-corrected dollars. If there is significant price inflation over the period of time being examined, the dollars in later years are worth less than dollars in earlier years. So, we use a price index (like the consumer price index, or the producer price index of the Gross National Product deflator) to adjust the benefits and costs for inflation.[2] We pick a base year, set the price index equal to 1.00 for that year, and express the value of a dollar as the inverse of the price index for other years. It actually doesn't matter which year you choose for a base year, so long as you are consistent.

After correcting for inflation, we want to consolidate the whole series of annual values into a single number called the net present value (NPV). This makes it possible to compare two or more uneven streams of costs and benefits over time. In a present value calculation, future values are "discounted" using an interest rate that reflects annual rates of return on capital. The discount factor for each future year is just the inverse of one plus the interest rate. Algebraically, the procedure looks like this:

$$NPV = \sum_{t=0}^{N} \left(B_t - C_t\right)\left(\frac{1}{1+i}\right)^t$$

where B_t is the benefit in year t, C_t is the cost in year t, i is the interest rate used in

2- This inflation-correction procedure is of course, unnecessary if the original cost and benefit projections were made assuming no inflation.

discounting expressed as a fraction (i.e. i = .07 for a 7% interest rate), and N is the number of years the project is expected to endure.

Incidentally, if decision makers are more comfortable thinking of costs or benefits on an annual basis, rather than in a lump sum figure like NPV, we can easily present the information in that way as well (or instead). The formula for equal annual payments that are equivalent to the NPV is:[3]

$$AnnualPayment = i \times NPV\left(\frac{1}{1-(1+i)^{-N}}\right)$$

The EIS documents for each FERC re-licensing case include net present value calculations, but different projects were evaluated using different base years for prices and different discount rates. While each project was evaluated correctly, the results were not comparable. Hence, to compare results across projects we had to dig into the details of each study, re-recreate the estimated time streams of costs and benefits, and calculate our own NPVs. That was a lot of work, for the student.

It would be easier if everyone used the same set of assumptions in economic assessments of projects, but there is no reason to expect that will ever happen. We can at least require that the documentation for such projects display the whole stream of cost and benefit estimates over the time span of the project, and that the inflation-correction and present value calculations be described explicitly.

Time Period

The time period over which the analysis is done matters as well. For example, if we're dealing with a project that produces some change in a river over a number of years, we will want an annualized cost for a fixed number of years (say, 50 years), preferably calculating each year's cost using a common interest rate and using dollars of common value. This would produce comparable numbers across projects. If one project is evaluated over 5 years and another is evaluated over a 25 year life, then neither the present values of the costs nor the equivalent annualized costs are strictly comparable.

What Interest Rate to Use

At the current interest rates in the US economy, I'd recommend a 2.6-3.7% rate for discounting benefits and costs of public projects. A look at the post-World War II history of the United States economy is helpful when considering inflation-corrected rates of return on various financial instruments. In Table 1, it is clear that short-term treasury bonds, longer-term bonds, and Moody's Baa rated bonds are all only slightly risky. Stocks (S&P) are very risky – the annual net return has varied from roughly –30% to +30% per year. As a general rule, higher rates of return are available on risky investments

Table 1. Average annual rates of return for various financial instruments (1947-1996)

	Nominal	Inflation Corrected
3-Month Treasury Bonds	4.93%	0.96%
10-Year Treasury Bonds	6.63%	2.60%
Moody's Baa Rated Bonds	7.69%	3.62%
S&P 500 Stocks	11.65%	7.43%

3- If you borrowed an amount equal to NPV and had to pay it back over 10 years with an interest rate of 8%, you could calculate the annual payment due at the end of each year by inserting N=10 and i = .08 in the formula.

than on less risky investments, i.e., shorter-term, less risky investments bring lower rates. Longer-term, higher-risk investments bring higher rates.

If we look at just the current year, we get a different impression. In fact, in the year 2000 the return on stocks generally was negative. Therefore, it is not helpful to look at only one year; we need to consider the average over a span of time. Deciding on the interest rate to use for present values or annualized values of a project should depend on the length of the project and the risk involved. A short term, risk-free project would be evaluated using the 3-month Treasury bill rate. For a longer-term, risky project we might discount using the rate of return on common stocks. Some restoration projects may well be packaged in a diversified way, keeping the whole portfolio risk low, in which case we might want to look at an interest rate in the low range. On the other hand, if we have a very risky project, we might want to use a higher discount rate to reflect that. Or, better yet, we could use an explicit model that incorporates the uncertainty in the decision criteria. For example, we might estimate probabilities of various outcomes for each project and choose a mix of projects that maximize the expected value of the restoration. In this latter case, we would not need to adjust the interest rates for uncertainty.

LIMITATIONS AND PROBLEMS IN ECONOMIC ANALYSES

Social values, pre-existing commitments, and property rights often preclude or limit the role of economic information in decisions. There are over-arching social and ethical concerns in some cases that overshadow economic consequences and make economic information less crucial to public decisions. A good example is the ESA, which has adopted a risk averse strategy declaring, in effect, that we're going to do whatever we need to do to prevent extinctions. The ESA does not say "depending on how much it costs." This strategy implies a limit to the appropriateness and usefulness of the economist's concern for balancing the costs of actions versus their outcomes (effectiveness or benefits). In effect, the "top level" decision to engage in a protective action for a threatened or endangered species is a higher social commitment. Nevertheless, cost-effectiveness can be a guide to choosing species preservation actions.

Another limitation is the inability to quantify social or economic equity. Most economic analysis tools used in project evaluation and policy analysis are focused on understanding the efficiency consequences of decisions. Efficiency is broadly construed in economic thought to deal with the entire range of concerns from technical efficiency to cost efficiency to maximizing net benefits from public programs. Little of the analytical apparatus is directly helpful in assessing the social values associated with equity – whether the actions taken distribute the costs and benefits in a way the we would generally accept as just. Still, the data that supports an assessment of economic efficiency can be turned to the task of describing the distribution of costs and benefits among classes of people. The classes can be defined as economic classes (poor, middle income, rich), or geographic populations (communities), or as economic functional classes (farmers, fishermen, government workers, stock holders), or as ethnic classes. In any case, the economic information can be used to display some of the important equity consequences along with the efficiency consequences. Economists have no more to say about the relative worthiness of various distributions of consequences than do other philosophers (which is to say a lot, but that is a story for another day).

Property rights associated with salmon habitats are evolving and changing under the influence of the ESA and due to the rise of innovative institutions like the Oregon and Washington Water Trusts (Whittlesey and Wandschneider 1992). Still, incompletely defined and non-transferable property rights can make calculation of economic values difficult. And even when heroic efforts to estimate values are successful, lack of property transferability can make the economic values fairly irrelevant to policy choices. Take agricultural water rights as an example. Agricultural economists have repeatedly shown that water diverted for agricultural use in arid areas has value as both input to crop production and as instream flow. But water rights were historically awarded only for "beneficial use" outside of the stream. And, worse, those water rights were allocated based on "first in time, first in right" and are largely non-transferable. So, a farmer with senior water rights has an economic incentive to hold onto and continue to use those rights even when the value of the water would be much greater in some other use (as instream flow or in use by a different water user downstream). So, one may find that a very sensible transfer of water from low-valued to high-valued use is essentially impossible to arrange. This is changing slowly and sporadically, as some states (Oregon, in particular) have passed legislation which gives instream flow rights some standing and permits holders of off-stream diversion rights to maintain ownership when they lease the rights for instream flow.

Another limitation is poor information about either the costs of taking action or the consequences of taking actions. We typically have inadequate data, and we face other issues that make reliable estimates of costs, effectiveness, or benefits impossible. Many times there is no good accounting system that allows us to track back from restoration measures in the field to expenditures at the agency. We know the overall budget by functional category (by agency unit and by labor versus materials costs), but it requires a real sophisticated cost accounting system to group costs logically for defined salmon restoration objectives. Further, when specific causes for species decline or recovery are difficult to determine and quantify, agencies tend to act in a crisis mode, without full consideration of consequences. Hence, decisions sensitive to cost-effectiveness and quantitative balancing of costs and benefits may be deemed too difficult or unnecessary.

Economics and the Endangered Species Act

The ESA process occurs in six stages (see Table 2): (1) the listing decision, (2) the designation of critical habitat, (3) jeopardy determinations (in which the Secretary of Interior or Commerce issues a "biological opinion" that a Federal agency program does or does not jeopardize an endangered species), (4) Section 7 interagency consultations (in which the action agency consults with the listing agency to avoid jeopardizing a species), (5) Section 7 exemption process, and (6) recovery planning and management. The extent to which economic factors can be considered in each stage is determined by the text of the Act, the legislative history of the Act, administrative discretion exercised by Federal agencies, and legal actions initiated by public interest groups or environmental activists. As noted in Table 2, economic information can be considered (a) in weighing the benefits of including an area in critical habitat against the benefits of excluding that area, (b) in evaluating alternative Federal agency actions to avoid adversely impacting a listed species or its habitat, (c) in appealing for a Section 7 exemption by the Endangered Species Committee, and (d) in estimating the cost of recovery measures considered in the Recovery Plan.[4] Economics has not been important in naming critical habitats,

4- See Gleaves and Wellman (1992) for a more extensive discussion of economics in the ESA process.

Table 2. Summary of ESA steps and economic contribution to decisions

Steps in ESA Decision Process	Scope for Economics	Apparent Importance of Economics in Decisions	Economic Concepts or Analytical Method
1. Listing Decision	None officially *but budgetary limits slow consideration of listings*	None	None
2. Critical Habitat Designation	Consideration of economic impact. Weigh benefits of including an area against benefits of excluding an area	Broad prohibitions on "taking" make this less important than ESA language suggests	Techniques for quantifying costs and benefits applied to additional restrictions on use of habitat
3. Section 7 - Findings of Jeopardy or No-Jeopardy	None — exclusively a biological/ecological assessment	None	None
4. Section 7 - Formulating Alternatives to Avoid Jeopardy	Agencies seek to comply with ESA while minimizing loss in services delivered to constituents	This is a very active area of activity under Federal ESA administration	Main methods are cost analysis and cost-effectiveness
5. Exemption from No-Jeopardy Mandate (Endangered Species Committee)	Explicit consideration of substantial economic loses due to Agency compliance	Economic assessment would seem to be an integral element of case for exemption	Economic cost and "impact" analysis are particularly relevant
6. Recovery Planning	Explicit call for "time and cost" assessment; weighing of economic consequences in planning	Economic evaluation of alternative approaches could be extremely useful, subject to biological uncertainties	Full suite of cost and benefit evaluation tools organized in a cost effectiveness analysis

because no specific action (and, hence, no specific economic consequences) are entailed in the critical habitat designation. On the other hand, the Section 7 exemption process is tantamount to the determination that social costs of species preservation are "unacceptably large." By a majority vote of at least five to seven, the Committee may grant an exemption, if they determine that:

(i) there are no reasonable and prudent alternatives to the…action; (ii) the benefits of such action clearly outweigh the benefits of alternative actions consistent with conserving the species or its critical habitat, and such action is in the public interest; (iii) the action is of regional and national significance; and (iv) neither the

> *federal agency concerned nor the exemption applicant made any irreversible or irretrievable commitment of resources prohibited by subsection (d) of this section.*[5]

While economic costs are clearly a major factor in appeals for exemption from the Endangered Species Committee, that process is rarely invoked.

Since the 1978 ESA amendments created the exemption process, the Committee has voted on only three applications: the Tellico Dam, the Graylocks Dam, and some Bureau of Land Management timber sales in the Pacific Northwest. Exemptions for the Tellico and Graylocks Dams were denied by the Committee. When the Bureau of Land Management (BLM) applied for exemption from ESA obligations for the sale of 44 tracts of timber, the Endangered Species Committee exempted 13 of the 44, denying exemption for 31 tracts. Several months later, however, the BLM withdrew its application for exemption, without having proceeded with the sale of the approved 13 tracts. So the exemption process has not become a significant route around the requirements of the Act. But it is always possible that claims of extreme cost or economic disruption can be taken directly to Congress, which can always provide a special exemption. This is exactly what happened with the Tellico dam.

Distribution of Costs and Equity Issues

The costs of a habitat restoration effort may be imposed upon one community, while some other community stands to gain the benefits of salmon restoration. For example, coastal communities typically receive benefit from ocean salmon fishing, while some costs of habitat protection impact inland communities. The regional economic implications among those communities may be a crucial factor for regional decision makers. Sometimes one community has five major sources of income, but another has only one or two. How resilient is the community where the salmon recovery costs are imposed? Such regional equity types of questions can be considered in a broader economic analysis of regional impacts.

I don't think that the economists who do these analyses are the ones who should be asked to determine an equitable distribution of costs and benefits among discrete communities. What we should be doing is providing information so that decision-makers can properly understand and weigh these kinds of issues. Decisions should be informed by information about geographic distribution of program costs on isolated communities without resilient economies, and about the locations of eventual benefits of recovery. If that information is not presented, decision makers are not going to be able to weigh the equity issue appropriately. To alleviate costs imposed on farmers and landowners, for example, the government (or non-governmental organizations) could provide financial assistance and initiate programs to soften the blow of reduced employment in rural communities.

Think about the John Day basin for example. There are people raising cattle, growing grass hay, and eking out a living along the river. If we have them give up some of their land by fencing streamside buffers, reduce their water diversions, and build manure ponds to control run-off of cattle feces, that will impose lower incomes on the farming operations. A full economic assessment of benefits and costs would include these lowered incomes as opportunity costs of the recovery effort. So here's a landowner faced with some real tangible costs that, maybe, will increase the potential fishing benefits to someone out in the ocean or in the Columbia River. The benefits largely are going to occur in the ocean and lower rivers, although there may be some

5- ESA section 7 (h)(A).

angling and fishing in the John Day River itself. But most of the benefits of an increased run is going to occur out of sight of the farmers. That's a tough trade-off for a landowner, especially one who is not making a fortune in farming. There is also a huge risk there, because improving stream habitats in the John Day will help salmon and steelhead only if a whole sequence of other things also happen. That is, the downstream people have to also cooperate by improving habitat and access, and the fisheries have to cooperate by not overfishing that stock.

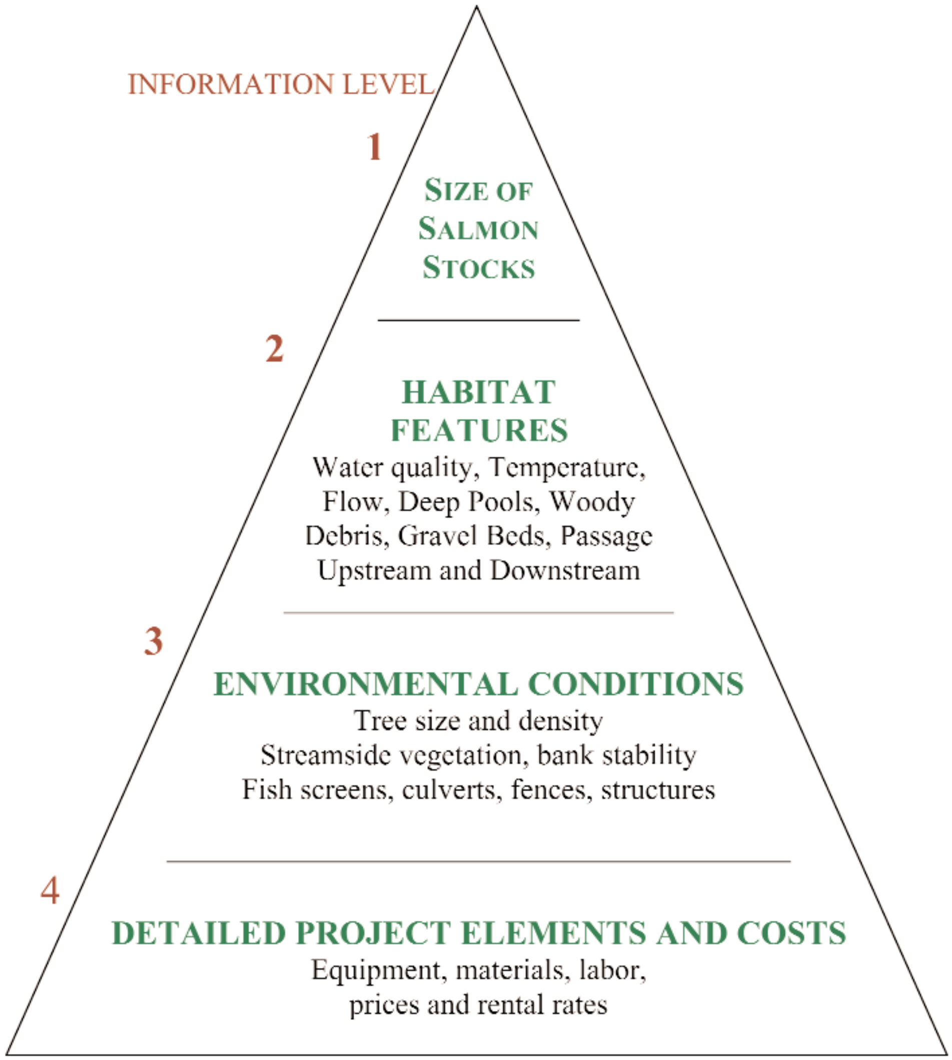
To get the landowners on board, you might compensate them for some of the potential losses. I think that's why the Conservation Reserve Program has allocated $500 million dollars to the Oregon-Washington-Idaho area. You can get landowners to accept a riparian conservation program that pays them a fair rent, or at least a respectable share of the cost. In essence, we're telling them, "We're going to rent this riparian area and we'd like you to manage it in the following way." They are not being asked to make un-rewarded personal sacrifices for some distant, risky benefits. The disparity between location of costs and benefits can provide a rationale for a compensation program. The economist needs to point out where the benefits and costs are occurring, so that decision processes can consider and deal with the economic equity issues that arise.

The problem of eco-ecosystem complexity

It is commonly understood that both the ecological and economic systems are multidimensional, dynamic, and interactive systems. One of the fundamental limitations of this discussion is that we are taking actions to modify certain physical aspects of the environment and then measuring what benefit that may have for a single species or a list of species. But there are, in fact, all sorts of other things that result from that physical modification. We might be controlling water flow for migration of juveniles, which may unintentionally change downstream water temperature. Or we might control erosion to improve spawning gravel, and that may affect flood control problems downstream. So, this is just a fundamental limitation of talking about a single species or even multiple species of salmon. The unintended effects are going to be a problem in applying some of these analytical techniques in developing recovery plans. While everyone seems focused on the recovery plans for the salmon species, they are not evaluating what it is doing for other species and unrelated effects beyond the purview of the recovery plan. Similarly, when costs are imposed on one element of the economic system, this often creates opportunities for gain by some other element of the system.

When the various ecological and economic factors are tightly linked it is actually going to be very difficult to do a thorough cost-benefit analysis. What you really need is the net cost and net benefits of all the consequences of an action. For example, in evaluating a proposed flow augmentation from the Snake River down through Hell's Canyon through the Lower Snake and into the Columbia, it turns out that not diverting water for irrigated agriculture in Idaho has both an opportunity cost to the farmers and a benefit to hydroelectric power producers downstream. When you increase the river flow for salmon migration, you also increase hydropower. So, when we assessed the cost of the Snake River flow augmentation, we took the reduced value of crops as a cost and then subtracted the increased value of hydropower to get a net cost (cost minus associated benefits) (Huppert 1999, p. 487). You can also imagine a case where some measure helps the salmon but also creates a recreational opportunity or improves the habitat for another species or harms another species.

Figure 1. Pyramid of information



Not everything that is good for salmon is good for everything else.) Once you start recognizing the multiple effects of these things, both economically and biologically, you are forced to look at a number of benefits that might accrue, either inadvertently or as a by-product of the restoration program, and to subtract the value of those benefits from the direct costs to come up with the net costs of the restoration. What that means is you can't get away from benefit estimation. Because some of the ancillary or unintended effects of restoration actions will create economic benefits which need to be assessed in order to determine the net costs of the restoration.

A BIGGER PICTURE

How do all these forms of analysis integrate with the economists' concerns about balancing benefits and costs, or at least being cost-effective, in salmon habitat restoration? Perhaps a good way to look at it is as a pyramid of information (Figure 1). At the very top of the pyramid (Level 1) would be some measure of salmon restoration, whether it be increased spawning run size, or increased spawning capacity of particular stream, or increasing sustainable catch, or even an index of spawning activity like the number of "redds." These constitute indicators of success in salmon population restoration.

Below that (Level 2) would be features important to functioning salmon habitat, like water quality, water temperature and flow, the presence or absence of deep pools and woody debris, the quality of the gravel beds for spawning, and so forth. These include the things that a field biologist can go into a stream and monitor. These are conditions that impact salmon, indicators of habitat quality or capacity.

Below that in the pyramid (Level 3) are broader environmental conditions that sustain and support salmon habitat quality, the underlying ecological structures. Late successional/old-growth timber in lower watersheds, streamside vegetation, sources of gravel bars would be important here. Also included would be human engineered features, like fences that keep the cattle away from streams, fish screens on water diversion structures, and properly engineered road culverts.

At the bottom of the pyramid (Level 4) are the specific inputs that have direct costs. Materials, personnel, supplies, and energy to assess habitat needs, plan projects, and carry out restoration efforts. These are the stuff of budget processes. What project inputs are used at what cost to change structural conditions to get improved habitat quality to successfully restore salmon populations? Normal accounting practice provides documentation of the human inputs to these projects; they are measured in terms of personnel hours, materials, supplies, and overhead.

Any given project planning/budgeting exercise must deal with at least the bottom two or three levels of this pyramid. Engineering/design teams typically develop a slate of inputs and related costs for a project to achieve some structural design criterion. For example, to fence five miles of stream over rough terrain and to re-plant streamside vegetation, the design team would determine needs for labor, materials, vehicles, and so forth. The cost estimate for the project is just the sum of these input costs. At Level 4 in the pyramid we have the information needed to discuss budgets: which categories of resources are directly used in changing the structure of that habitat, which cause changes in the conditions directly faced by the salmon.

The link between the top and bottom levels of the pyramid, however, is of fundamental importance to an economic assessment of the program. For either benefit-cost or cost-effectiveness analysis we need ultimately to link the expenditures on project inputs to the indicators of salmon restoration success. However, it is getting from the bottom of this pyramid to the top that can be a major problem for analysts. The quantitative link between the top level and the specific restoration projects is often fraught with uncertainty, theory, and controversy. Because salmon (especially coho, steelhead, and chinook) utilize such widespread features of the natural landscape over their life stages, each segment of the habitat can become a limiting factor. Is it spawning gravel, or deep pools for juveniles, or water flow during migration, or estuarine feeding areas, or ocean conditions, or upstream migration blockages that limit a particular salmon run? If the project being contemplated does not release the population from a binding constraint, then the project may achieve no significant success in augmenting the salmon population. And if the population does not increase, then there is no effectiveness and no economic benefit.

If we think about this in terms of basic microeconomics, we know that a "cost equation" reflects the accountant's budget; it is the sum of the price of inputs times the amount of those inputs; it is the wage rate times the hours and labor used, and the price of supplies times the number of supplies and the cost of renting times the square feet of office space, etc. All of these add up to costs estimated for project budgets. In order to do cost-effectiveness analysis, however, we use a more complex concept – the "cost function" which relates level of output to total costs, as in, "How much does it cost to produce 25 automobiles versus 50 automobiles?" The answer to that question requires thorough understanding of how the cost inputs will be used and of how the desired outcomes can be engineered and achieved by use of these inputs. That is a much more challenging analytical task than is the compilation of budgets for projects. To estimates costs of achieving particular outcomes (like salmon restoration indicators), we have to understand how units of inputs translate into a level of outputs. In microeconomics, the functional relationship between inputs and outputs is termed the *production function*. Above, I have used the pyramid metaphor to describe the same kind of linkage, involving cost accounting, engineering design, physical relationships, and (in the case of salmon) ecological/environmental relationships. These are the several steps needed to identify the budgets, people, and materials going into restoration and figuring out how to relate the costs to the outcomes that reflect project effectiveness or project benefits.

The above discussion suggests that the role of economists in the habitat restoration decisions is twofold. One is to help conceptualize the nature of the information requirements and choices being made. The other is — in collaboration with biologists, engineers and ecologist — to collect information and quantify the underlying technical and ecological relationships, so that the cost and benefits of specific projects can be displayed with enough confidence to justify attention by decision makers.

RECOMMENDATIONS

The outcome of our work responds to a need expressed by various planners and resources managers and emphasizes the need to develop generalized cost assessment techniques to improve decision-making. A systematic approach to reporting actual costs can resolve some of the issues related to uncertainty, as will sharing project experience. In addition, the more information that is shared across projects, the better restoration cost information will be more generally. Finally, as more projects are completed, maintenance and monitoring will become a much larger issue. The latter may suggest a need for more sampling and studies to look at these costs.

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